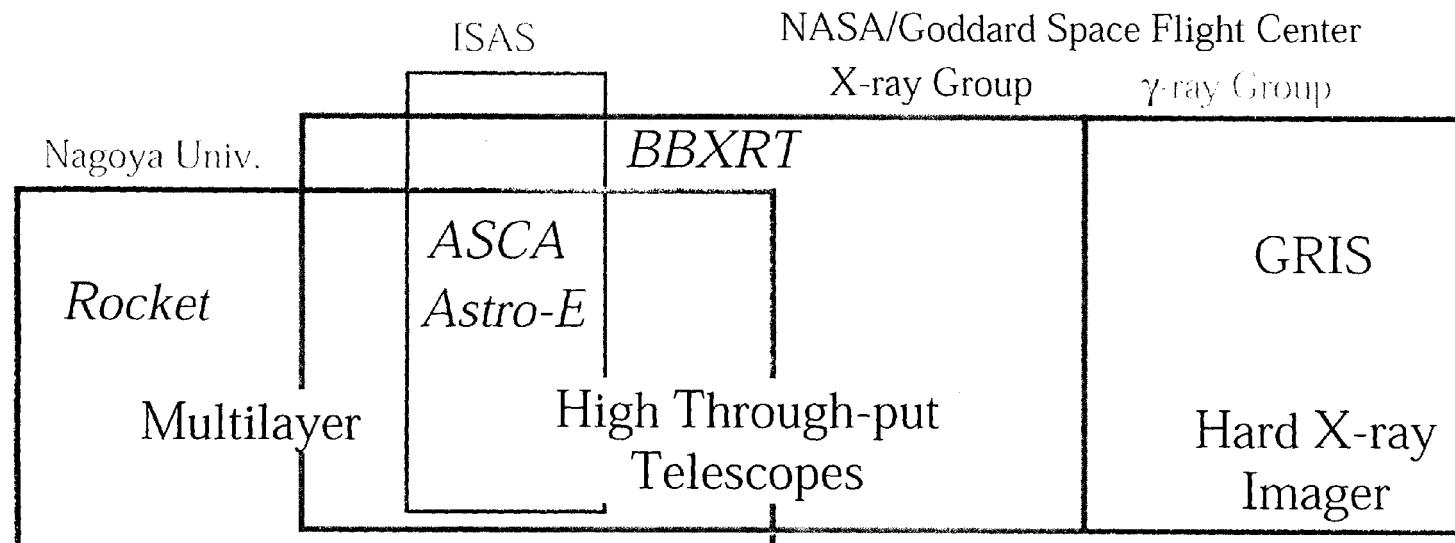


Developments of  
Multilayer Supermirror  
Hard X-ray Telescopes

Hideyo Kunieda  
(Nagoya University)

Institute of Space and Astronautical Science



Supermirror

Replica Foil

CdZnTe  
Detector

Demonstration Model (1997)

InFOC $\mu$ S(2000)

Astro-G(2007?)

Constellation-X

XEUS(2010~)

## Telescope Parameters

	ASCA	Astro-E		InFOCμS	Astro-G
Diameter	345 mm	400 mm		400 mm	600 mm
Focal Length	3500 mm	4500	4750	8000 mm	7000-8000
Incident Angle (Mini)	0.25 °	0.19	0.18°	0.11°	0.12°
(Max)	0.71°	0.64	0.60°	0.36°	0.61°
Coating	Au	Pt	Au	ML	Pt/ML
No. of telescopes	4	1	4	1(4)	6
Effective Area(1.5keV)	1200	500	1700	-----	8000
(7 keV)	480	350	1100	-----	6000
(30 keV)	----	----	----	100	400
Image Quality	3.6' HPD	2'		2'	30-40"(TBD)
Launch Year	1993	2000		2000	2007?

# Supermirror design

## 1. Optimized for the balloon experiment

Ignore the low energy response below 20 keV

← Atmospheric absorption

Minimum number of layer pairs

→ Shorter production time)

Flat topped response

→ Wider field of view

→ Less spectral features

## 2. Block method

Constant d in a group of layers

→ Clear design scheme

→ Easy evaluation of reflectors

Equivalent in performance to the continuous design

## 3. Foil grouping

More than 200 foils are put into 10 – 15 groups of foils

→ Easy set up for ML deposition

→ Redundancy of foils in a group

## 4. Total Expected Performance

Effective Area

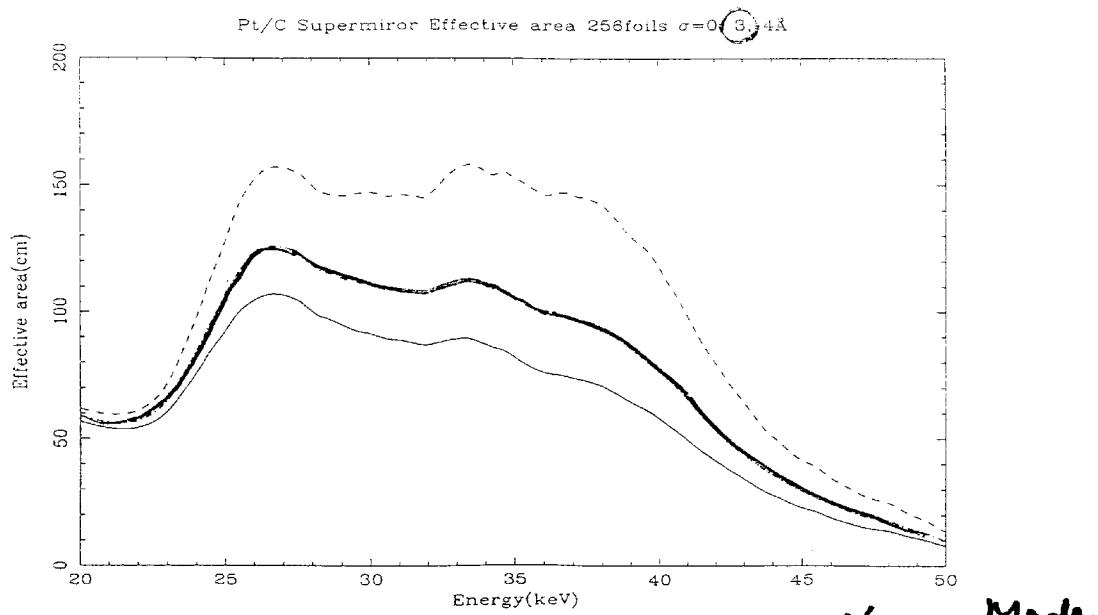
70-100 cm<sup>2</sup> ( $25 < E < 35$  keV)

Sensitive to the interfacial roughness

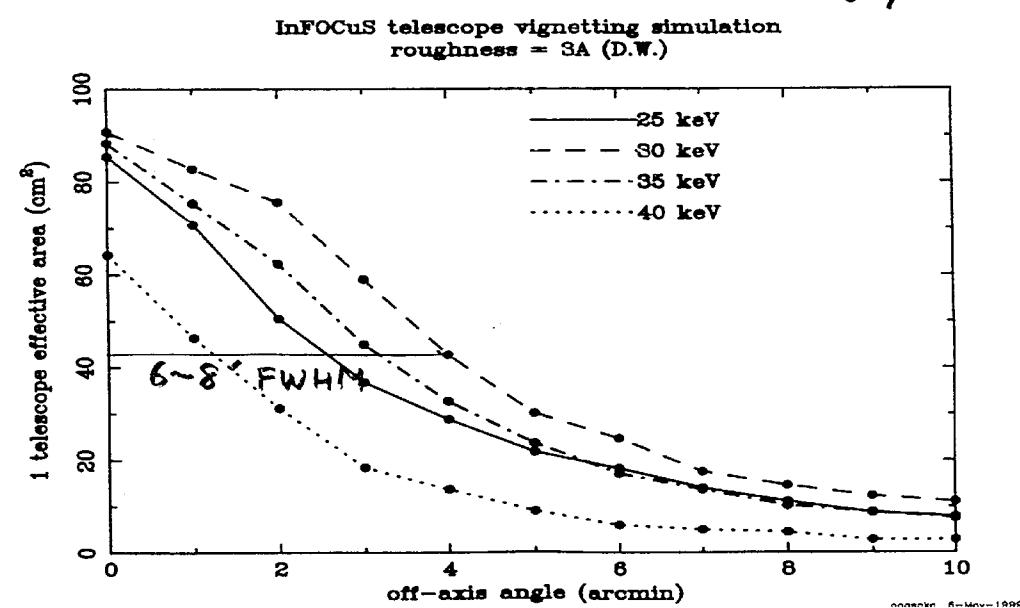
Field of View

6 – 8 arcmin (FWHM)

Depending on the drop of area at boundary energies

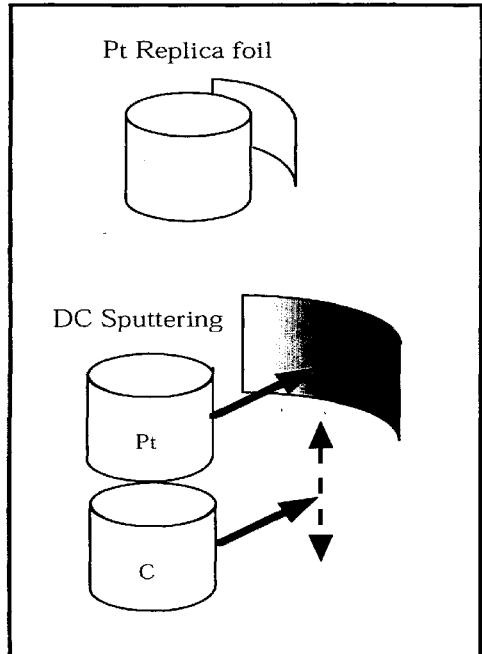


*Nagoya Mode*



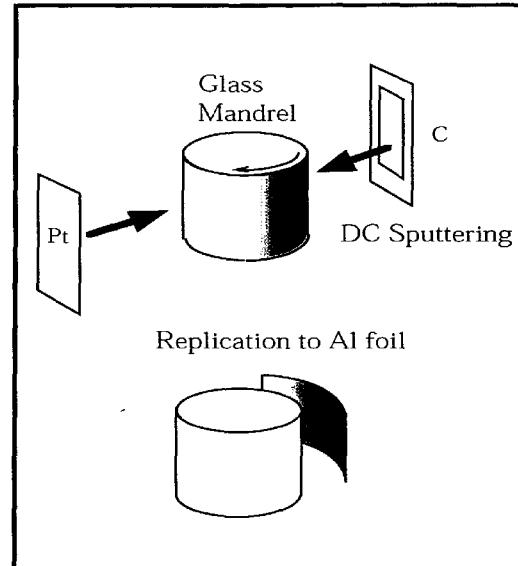
# ML production and reflectivity

Sputtering to Replica Foil

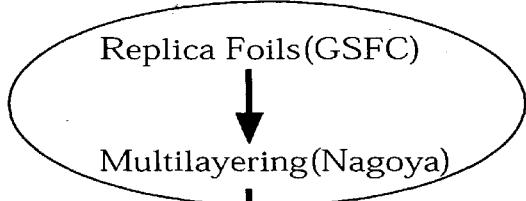


Established Process

Direct Replication



Successful with the pilot system  
at Nagoya in 1997



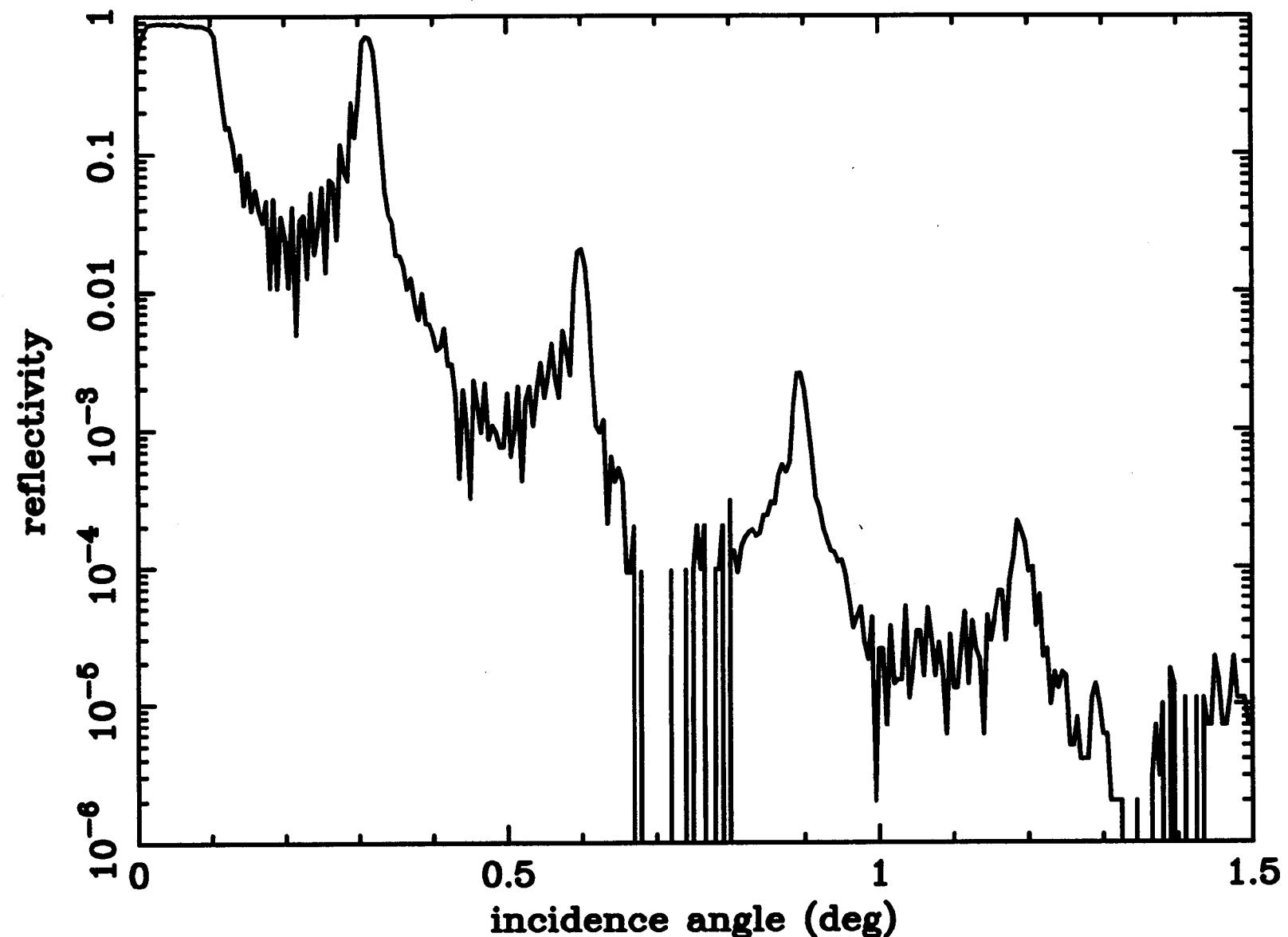
1000 foils

Established at GSFC

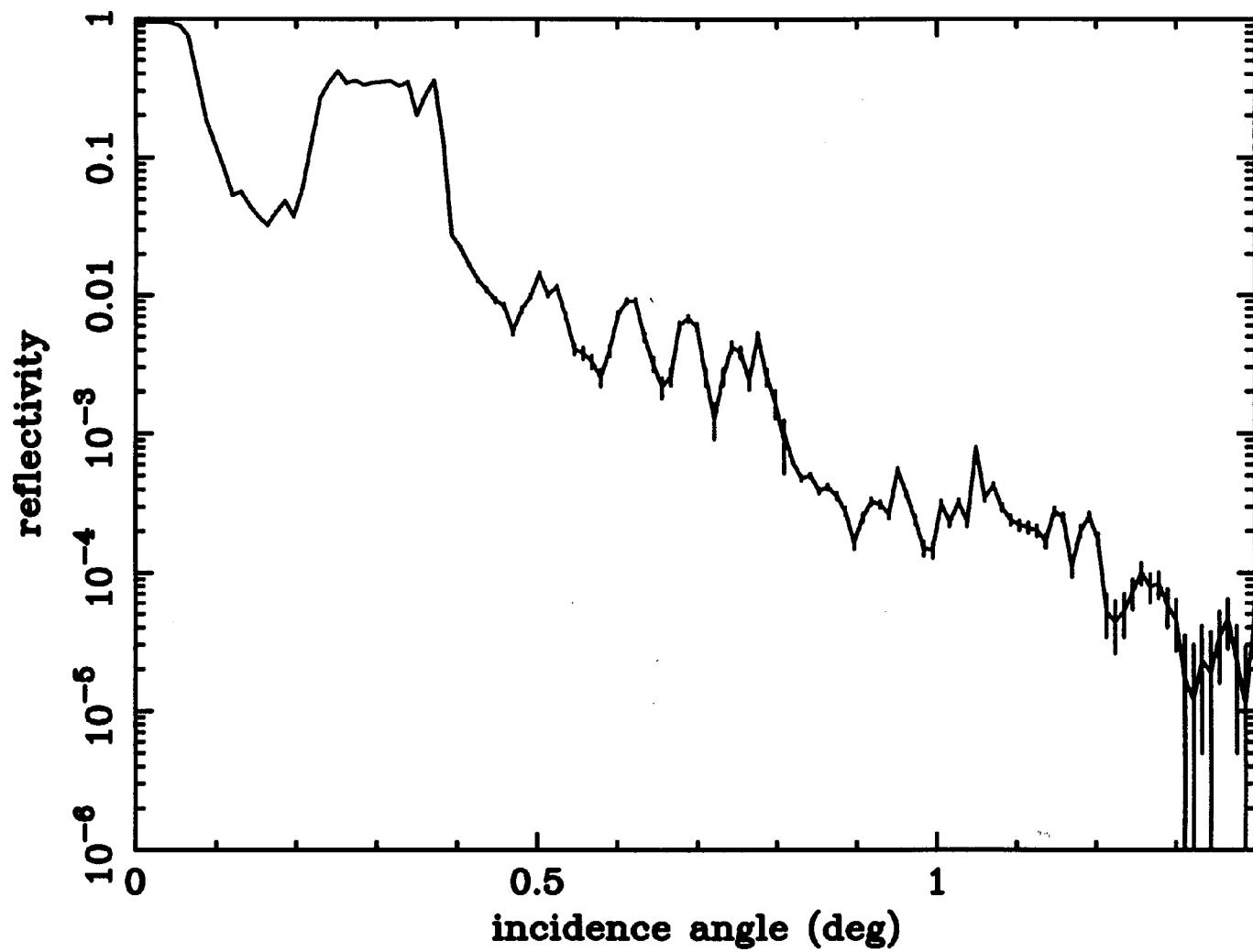
1000 foils

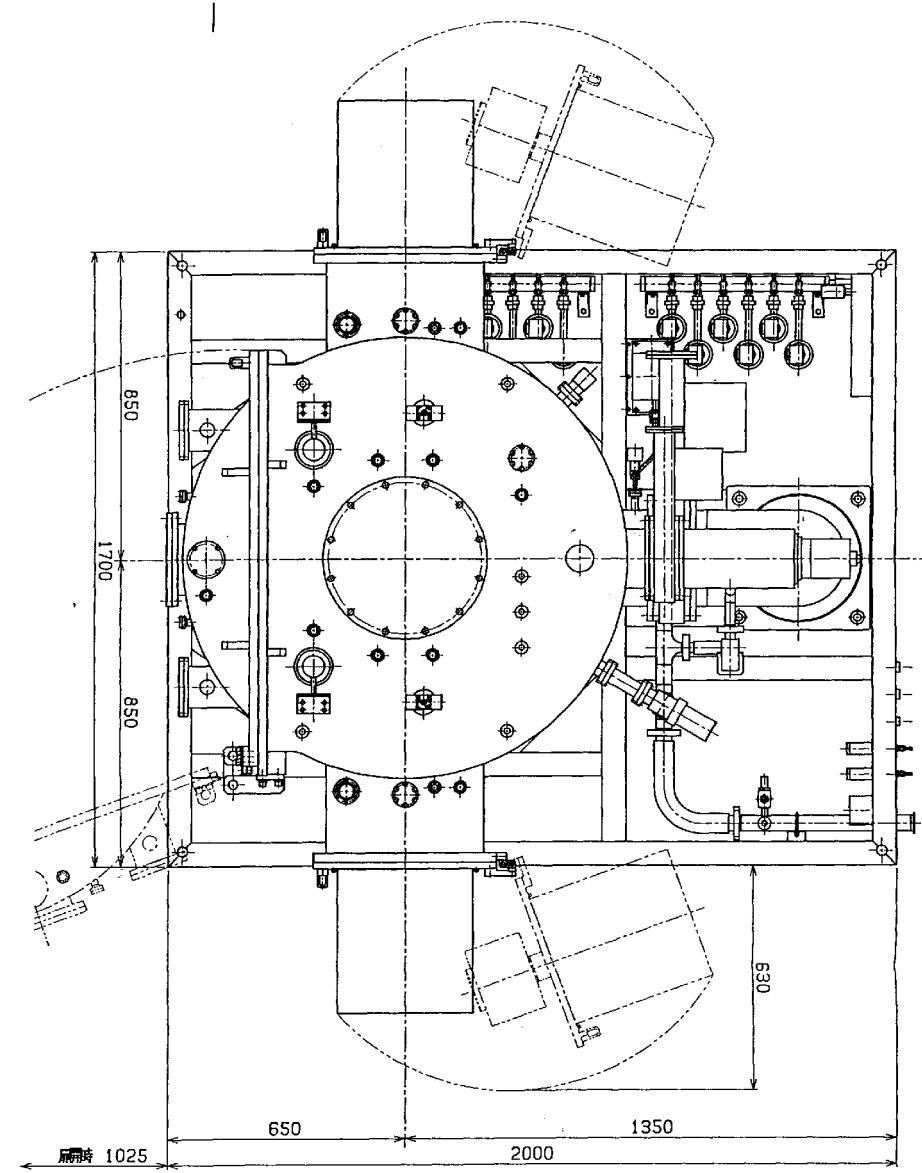
The first telescope  
for InFOCuS

Pt/C multilayer  
 $d=37.5\text{A}$ ,  $\gamma=0.44$ ,  $N=20$ , measured at 32 keV

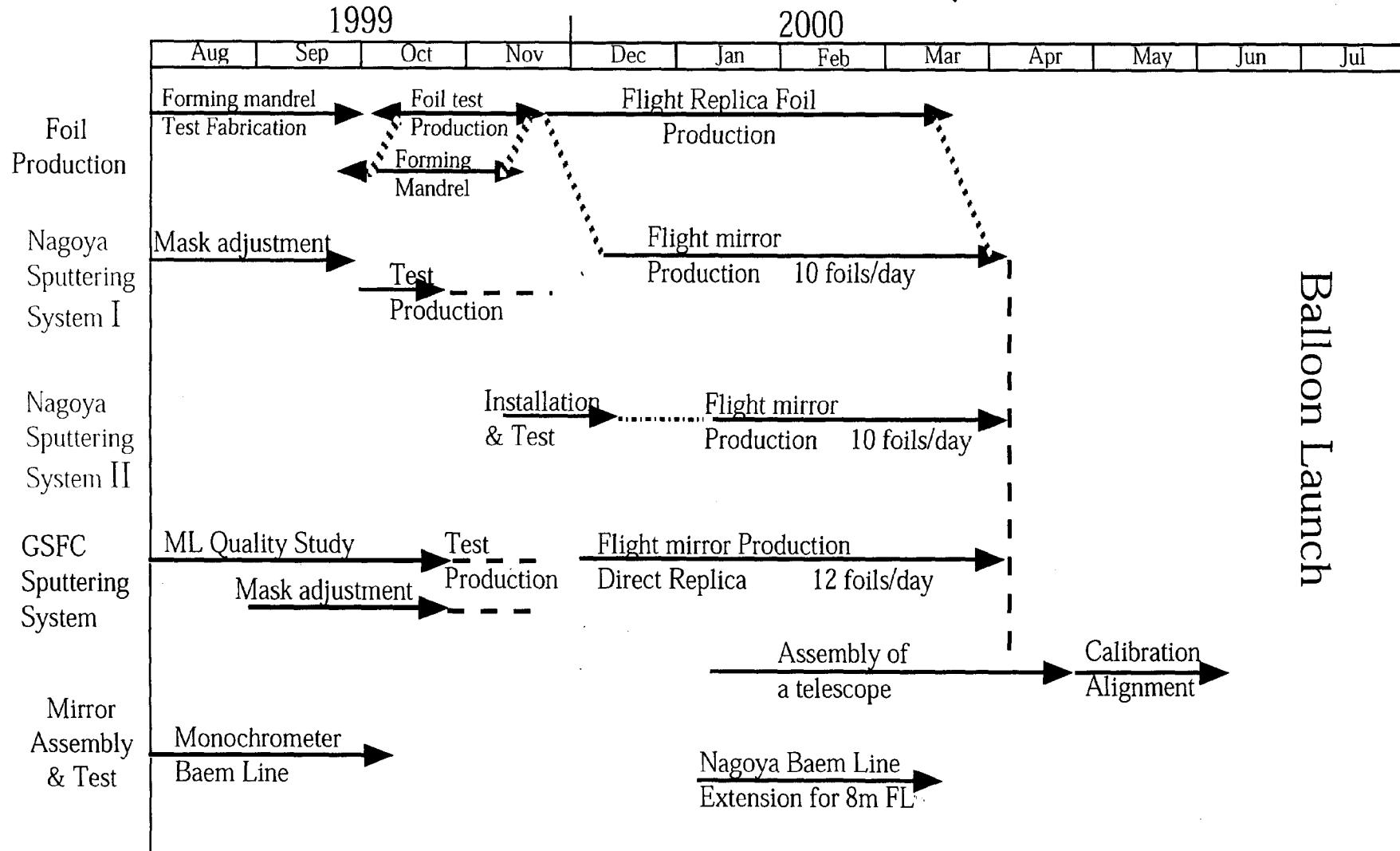


Pt/C 5-block Supermirror on Pt replica foil  
 $d=31-56\text{ \AA}$ ,  $\gamma=0.40$ ,  $N=68$ , measured at 32 keV

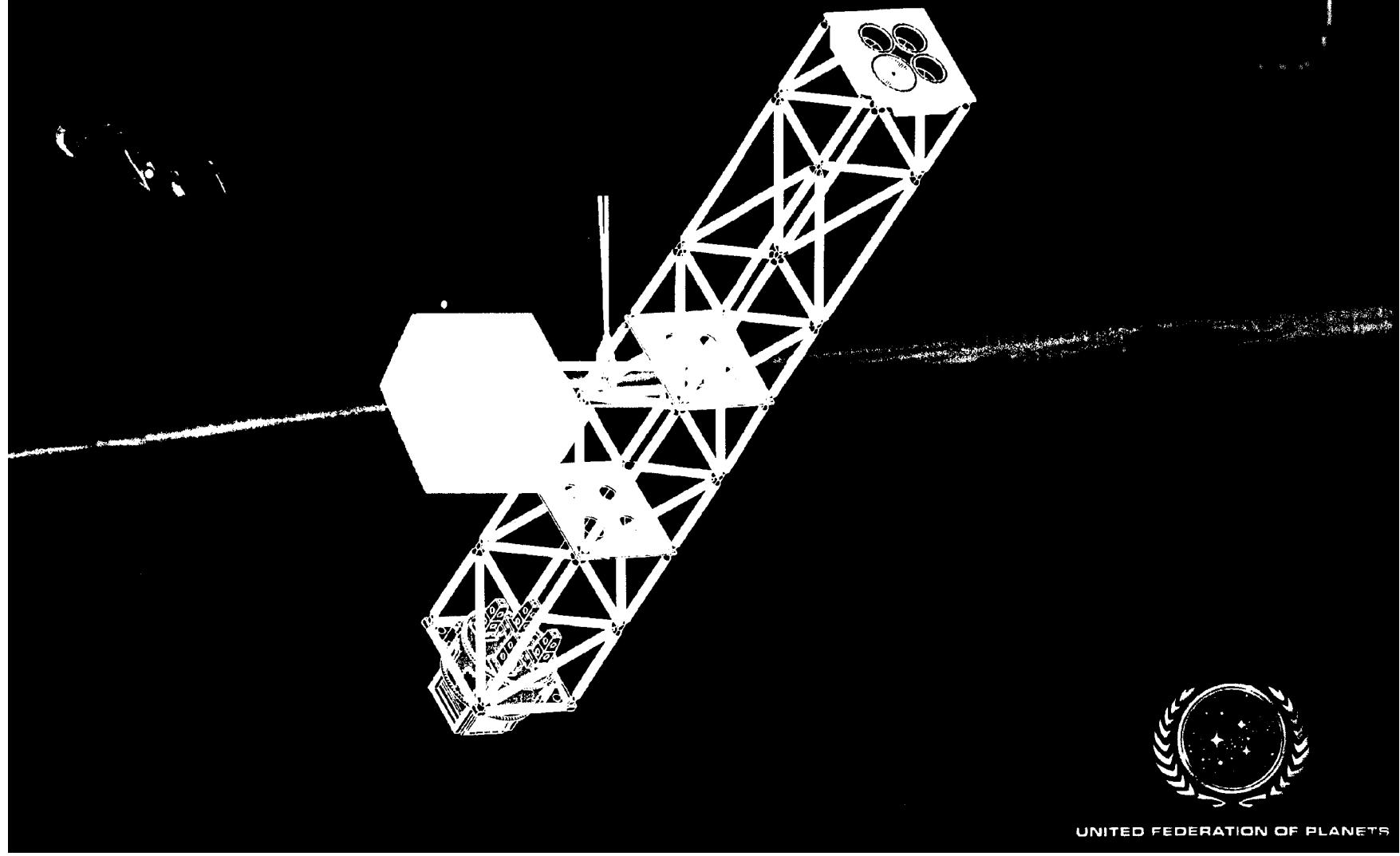




# Master Schedule for InFOCμS



InFOCUS



UNITED FEDERATION OF PLANETS

# Future Developments

## 1. Image Quality

Substrate

Al Thickness/stiffness

Glass sheet? Other material?

Electro-forming Ni is ten times heavier

Thickness (factor of 3) x Density (factor of 3)

Mandrel

Glass cylinder has waviness of about one arcmin.

Super-polished mandrel is extremely expensive.

Support system

Margin of the alignment grooves allow arcmin fluctuation

Monolithic replication of two stages

## 2. Multilayer

Satellite design

Optimizing scheme for broadband response

Higher energy

Extension of energy band up to 100 keV (Ti44; 68, 78 keV)

Characterization at high energies

Small  $\sigma$

Degradation of reflectivity by the interfacial roughness.

Thinnest period ( $d > 20 \text{ \AA}$ ) could be improved.

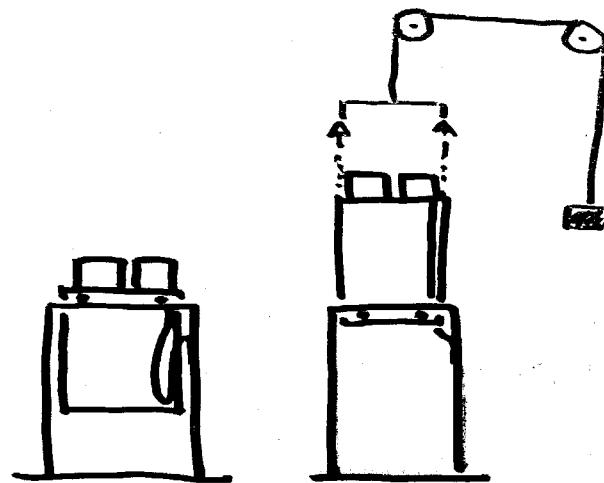
## Extensible Optical Bench of ASCA and Astro-E

	ASCA	Astro-E	Constellation-X
Extension Length	~1.2 m	~1.8 m	~7 m
stages	1	1	3
Moving Part	4 XRT	5 XRT	Detectors.
Accuracy	( $<1'$ )	$<0.5'$	?

④ Gravity  $1G \rightarrow 0G$

• Measuring System?

• Actuator?



FL=7m d=12-60cm (d=12-40cm for ML) x 6 telescope

